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ORIGINAL RESEARCH

OVERHEAD DEEP SQUAT PERFORMANCE PREDICTS FUNCTIONAL MOVEMENT SCREEN™ SCORE

Daniel R. Clifton, MEd, ATC[1]
Dustin R. Grooms, MEd, ATC[1]
James A. Onate, PhD, ATC[1]

ABSTRACT

Background: The Functional Movement Screen (FMS™) has been suggested for use in predicting injury risk in active populations, but time constraints may limit use of the screening test battery. Identifying one component of the FMS™ that can predict which individuals may perform poorly on the entire test, and therefore should undergo the full group of screening maneuvers, may reduce time constraints and increase pre-participation screening utilization.

Purpose: The purpose of this study was to determine if performance on the FMS™ overhead deep squat test (DS) could predict performance on the entire FMS™.

Study Design: Cohort study.

Methods: One hundred and three collegiate athletes underwent offseason FMS™ testing. The DS and adjusted FMS™ composite scores were dichotomized into low performance and high performance groups with athletes scoring below 2 on the DS categorized as low performance, and athletes with adjusted FMS™ composite scores below 12 categorized as low performance. Scores of 2 or above and 12 or above were considered high performances for the DS test and adjusted FMS™ composite score respectively, and therefore low risk for movement dysfunction and potentially, injury.

Results: Individuals categorized as low performance as a result of the DS test had lower adjusted FMS™ composite scores ($p < 0.001$). DS scores were positively correlated with adjusted FMS™ composite scores ($\rho = 0.50$, $p < 0.001$). Binomial logistic regression identified an odds ratio of 3.56 (95% CI: 1.24, 10.23, $p = 0.018$) between DS and FMS™ performance categories.

Conclusions: Performance on the DS test may predict performance on the FMS™ and help identify individuals who require further musculoskeletal assessment. Further research is needed to determine if DS performance can predict asymmetries during the FMS™.

Level of Evidence: Level 3

Keywords: Injury risk assessment, injury prevention, pre-participation examination, screening

[1] Division of Athletic Training, The Ohio State University, School of Health & Rehabilitation Sciences, Columbus, OH, USA

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CORRESPONDING AUTHOR
Daniel Clifton
228C Atwell Hall,
453 West 10th Avenue,
Columbus OH 43210
Phone: (716) 213-7620
Fax: (614) 292-1632
E-mail: clifton.95@osu.edu

INTRODUCTION

Musculoskeletal injury rates in high school and collegiate athletics have been reported to be as high as 6.6 injuries per 1,000 athlete exposures with the highest rates occurring during the pre-season.[1-3] It has also been reported that over half of musculoskeletal injuries occur in the lower extremity.[1] Lower extremity injuries can have long-term consequences such as chronic ankle instability, osteoarthritis, and decreased quality of life that can contribute to heightened recurrent injury risk, decreased physical activity and fear of injury with exercise.[4-8] Injury prevention strategies can be effective at reducing the risk of lower extremity musculoskeletal injury, however, a one program fits all approach may not be the most effective method.[9] In order to improve the effectiveness of injury prevention programs a proper musculoskeletal screening process must first be identified; musculoskeletal screening provides a means to personalize interventions to target individuals' specific functional impairments.

The Functional Movement Screen (FMS™) is a screening test battery developed to identify specific movement dysfunctions that may be related to musculoskeletal injury risk.[10,11] This screen consists of seven tests that assess mobility, stability, coordination, and postural control during seven dynamic movements.[10] These tests include the active straight leg raise (ASLR), shoulder mobility (SM), trunk stability push-up (TSPU), rotational stability (RS), in-line lunge (ILL), hurdle step (HS), and overhead deep squat (DS) (Figure).[10] The ASLR, SM, RS, ILL and HS tests are performed bilaterally.[10] The FMS™ may be valuable for identifying injury risk in a variety of active populations including professional football players, firefighters, high school athletes and military personnel.[10,12,13] Despite the potential value of the screen, anecdotal evidence suggests that resource constraints prevent widespread use. Time, staff, and monetary constraints may prevent health care professionals from administering this screen on all physically active individuals during pre-participation physical evaluations (PPE). Due to resource constraints, identifying one component of the FMS™ that can predict which individuals may perform poorly on the entire test, which could function as a quick red flag system to identify individuals that should undergo full screening, may reduce time constraints and improve screening cost-effectiveness, allowing more clinicians to administer this tool to assess pre-participation musculoskeletal injury risk.

One screening movement that may predict performance on the entire FMS™ is the overhead deep squat. This component is theorized to be a dynamic task that requires mobility and stability at multiple joints for correct performance.[11,14,15] Individuals who perform poorly on an overhead squat task have impaired mobility and stability in multiple lower extremity joints.[16-18] In theory, mobility and stability impairments during the deep squat should relate to performance on specific mobility and stability FMS™ tests such as the ASLR and TSPU, in turn relating to total FMS™ performance.[14] A recent factor analysis also identified the deep squat as a major contributor to FMS™ composite score.[19] Therefore, the purpose of this study was to determine if performance on the FMS™ overhead deep squat test predicts performance on the entire FMS™. Lower DS scores were hypothesized to be related to lower FMS™ composite scores. Specifically, individuals who received a DS score below 2 would receive an adjusted FMS™ composite score below 12.

METHODS

This cohort laboratory study was designed to determine if overhead deep squat test scores could predict FMS™ composite scores in healthy, collegiate athletes. There was one ordinal independent variable, overhead deep squat score, and one ordinal dependent variable, FMS™ composite score. The variables were considered ordinal because the DS score ranges from 0 to 3 and the FMS™ composite score ranges from 0-21 with higher scores indicating better performances.

Subjects

Eighty-five females (1.71 ± 0.10 m, 68.66 ± 9.81 kg) and eighteen males (1.97 ± 0.10 m, 96.82 ± 10.01 kg) participating in National Collegiate Athletic Association (NCAA) Division I athletics were included in this study. Subjects were included if they were participating in football, soccer, basketball, lacrosse, or volleyball and were medically cleared to participate in athletics at the time of the study. Subjects who were recovering from illness, surgery, fractures or other musculoskeletal conditions that precluded them from participating in athletic performance were excluded from the study. Participants were provided information, prior to agreeing to participate and signed informed consent documents after agreeing to participate. This study was approved by the university's institutional review board.

Procedures

Subjects provided informed consent prior to performing the FMS™ according to previously published protocol.[10] Each of the seven screening movements was scored on a scale from 0-3 with a higher score indicating better performance. The score from each test was summed to create a composite score ranging from 0-21 with a higher score indicating better performance.

For those tests that were performed bilaterally, the lower score of the two sides was counted towards the composite score.[10] The screen was administered by one FMS™-trained certified Athletic Trainer who was not blinded to the study objectives and the order in which the tests were performed was not randomized. The FMS™ has been shown to have fair to strong intrarater reliability with intraclass correlation coefficients ranging from 0.77 to 0.95 for novice and expert testers.[20,21] Additionally, the DS test has been reported to have good intrarater agreement ($k = 0.69$).[21]

Statistical Analyses

The FMS™ composite score in this study did not include the DS score to maintain independence of observations and therefore an adjusted FMS™ composite score ranging from 0-18 was used for analyses. The DS and adjusted FMS™ composite scores were dichotomized into low performance and high performance groups based on score. Individuals who scored a 0 or 1 on the DS were categorized as low performance. A receiver operator characteristic curve (ROC) was used to determine a cut-off value for dichotomizing the adjusted FMS™ composite score. The ROC curve identified a score of 12 as the best cut-off value for the 18-point adjusted FMS™ composite score. As a result, individuals who received an adjusted FMS™ composite score below 12 were categorized as low performance..

A Mann-Whitney U test was used to determine if there was a difference in adjusted FMS™ composite scores between DS performance categories. The relationship between DS performance category and adjusted FMS™ composite score was determined using a Spearman's rho correlation. A binomial logistic regression was used to determine the odds ratio between DS performance category and adjusted FMS™ performance category. The alpha level was set *a-priori* at $p < 0.05$.

RESULTS

Participants were comprised of men's basketball, women's basketball, and women's soccer players. Number of participants, median adjusted FMS™ composite scores and median DS scores with interquartile ranges (IQR) by sport are reported in Table 1. Median adjusted FMS™ composite and DS test scores with IQR for low and high performance categories are reported in Table 2; no individual received a score of zero on any individual FMS™ test. Individuals who were categorized as low performance as a result of the DS test had significantly lower adjusted FMS™ composite scores ($p < 0.001$). Low-performance

Table 1. *Median adjusted FMS™ composite score and overhead deep squat score by sport*

Sport	Number of Participants	Adjusted FMS™ Composite Score (IQR)	Overhead Deep Squat Score (IQR)
Men's Basketball	18	11 (4)	1 (0)
Women's Basketball	23	13 (3)	2 (1)
Women's Soccer	62	14 (3)	2 (1)

IQR = Interquartile range

Table 2. *Median adjusted FMS™ composite score and overhead deep squat score by performance category*

Test	Performance Category	Adjusted FMS™ Composite Score (IQR)	Overhead Deep Squat Score (IQR)*
Deep Squat	Low Performance (n=38)	12 (3)	1
	High Performance (n=28)	14 (2)	2
Adjusted FMS™ Composite	Low Performance (n= 25)	10 (2)	1
	High Performance (n=41)	14 (2)	2

IQR = Interquartile range;
*Overhead deep squat score IQR was 0 for each test at both performance levels

individuals had a median adjusted FMS™ composite score of 12 (IQR = 3) and high performance individuals had a median adjusted FMS™ composite score of 14 (IQR = 2). DS scores were positively correlated with adjusted FMS™ composite scores, indicating that better DS scores were associated with better FMS™ performance (ρ = 0.50, $p < 0.001$). Additionally, binomial logistic regression identified an odds ratio of 3.56 (95% CI: 1.24, 10.23, $p = 0.018$) between adjusted FMS™ composite and DS performance categories. This suggests that the odds of being categorized as low performance on the FMS™ is 3.56 times greater for individuals who were categorized as low performance on the DS test.

DISCUSSION

The main findings of this study indicate there may be a clinically meaningful relationship between DS and FMS™ composite scores. There is a moderate, positive correlation (ρ = 0.50) between DS performance category and adjusted FMS™ composite score, with 25 percent of the variance in adjusted FMS™ composite scores explained by DS performance. This indicates that better DS scores are related to better FMS™ performance overall. The results of this study also indicate that the DS test may be able to predict performance on the full FMS™ as the odds of scoring poorly on the adjusted FMS™ are 3.56 times greater for those who scored poorly on the DS. Predicting individuals who are more likely to perform poorly on the entire FMS™ may help identify individuals who are at greater risk of musculoskeletal dysfunction, and potentially, injury. The use of the DS as a simple, time efficient, primary screening tool to initially assess general movement dysfunction prior to in-depth screening is recommended during PPE assessments.

Previous research findings suggest that the FMS™ is valuable for predicting injury risk in physically active individuals.[12,13,22] Despite the potential benefits, anecdotal and research evidence suggests that resource constraints and cost-effectiveness concerns prevent the FMS™ from being widely administered.[23] Identifying individuals on the DS test who require further assessment may indicate a solution to time and cost-effectiveness concerns. A time-efficient process of approximately one minute per DS test versus approximately seven to ten minutes per the full FMS™ would expedite a system for identifying those who require further assessment. Additionally, using the DS as the first test in a hierarchical screening process to determine which individuals require further assessment may improve cost effectiveness of subsequent injury prevention programs.[23,24]

The relationship identified in this study may be present because the DS is a dynamic task that is believed to require mobility and stability throughout multiple joints for correct performance.[11,18] The FMS™ was developed on the theory that to perform a dynamic task correctly (e.g., overhead deep squat), an individual must first have proper mobility and stability at multiple joints; mobility and stability that is assessed by the ASLR, SM, TSPU and RS FMS™ tests.[11] This theoretical foundation is supported by Stiffler et al. who suggested that individuals who have dysfunction during an overhead squat may also have reduced mobility and stability in multiple lower extremity joints. Their research found that individuals who experienced dysfunction during an overhead squat also had reduced ankle dorsiflexion, increased pronation, and larger Q-angles.[17] Additionally, Bell et al. identified that individuals who had medial knee displacement during an overhead squat also exhibited decreased mobility as measured by ankle dorsiflexion.[16] Because medial knee displacement is a dysfunction that results in a lower deep squat score it can be theorized that a worse deep squat performance may, in part, reflect mobility deficits at the ankle.

Although the DS test may be beneficial for identifying individuals who require further assessment of musculoskeletal dysfunction and injury risk, the role of movement asymmetries in DS performance were not examined. Lehr et al. suggested that identifying asymmetries during FMS™ testing is valuable in determining injury risk.[25] It may be reasonable to believe that because the DS is a bilateral task, movement asymmetries may impair individuals' abilities to complete the movement adequately, although this cannot be assumed because the task is not intended to assess asymmetry. Additionally, the hierarchical structure of the FMS™ that theoretically requires mobility and stability for adequate DS performance also requires mobility and stability that is symmetrical.[11,15] Although DS performance theoretically should reflect movement asymmetries, further research should be performed to determine the exact relationship.

An additional limitation is that this study did not control for injury history. It is possible that relationships between DS performance and adjusted FMS™ composite score may be due to the influence that injury history may have on movement dysfunction. Future research should examine these relationships in individuals with and without a history of injury. Another potential limitation is that the study sample consisted of mostly females, 78.79 percent of subjects in this study were females, and further research should examine these relationships in a sample with equal numbers of males and females. Although the results mostly reflect a relationship between DS performance category and FMS™ performance category in females, it is not likely that this relationship would change if more males were included. According to a study by Abraham et al, FMS™ DS scores do not differ between sexes.[26] Although Abraham et al. identified a significant difference in composite scores between sexes with a mean score for males of 14.93[26] and a mean score for females of 14.17,[26] the FMS™ scoring system does not allow for fractions of a point so it is unlikely that this significant difference is clinically meaningful. Lastly, because the relationship between DS score and injury risk was not assessed the injury risk prediction capability of the DS test is unclear.

CONCLUSIONS

The odds of having a low performance adjusted FMS™ composite score, defined as a score below 12 on an 18 point scale, are 3.56 times greater for individuals who have a low performance DS score, defined as a score below 2. This finding, along with a moderate correlation between DS and adjusted FMS™ composite scores, indicate that there may be a clinically meaningful relationship between DS and FMS™ composite scores. Screening all individuals with the FMS™ may be impractical given resource constraints but the findings of this study may provide a possible solution. Clinicians who do not have the resources to administer the entire FMS™ to all patients may find it beneficial to administer the overhead deep squat test as an efficient method for identifying individuals who require further in-depth musculoskeletal injury risk assessment.

REFERENCES

1. Hootman JM, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. *J Athl Train.* 2007;42:311-319.
2. Agel J, Schisel J. Practice injury rates in collegiate sports. *Clin J Sports Med.* 2013;23:33-38.
3. Tolbert TA, McIlvain GE, Giangarra CE, Binkley HM. Injury rates in high school and collegiate athletics. *Strength Cond J.* 2011;33:82-87.

4. Hertel J. Functional instability following lateral ankle sprain. *Sports Med.* 2000;29:361-371.
5. Freeman M. Instability of the foot affer injuries to the lateral ligament of the ankle. *J Bone Joint Surg Br.* 1965;47:669-677.
6. Thelin N, Holmberg S, Thelin A. Knee injuries account for the sports‚Äêrelated increased risk of knee osteoarthritis. *Scand J Med Sci Sports.* 2006;16:329-333.
7. Roos EM. Joint injury causes knee osteoarthritis in young adults. *Curr Opin Rheumatol.* 2005;17:195-200.
8. Flanigan DC, Everhart JS, Pedroza A, et al. Fear of reinjury (kinesiophobia) and persistent knee symptoms are common factors for lack of return to sport after anterior cruciate ligament reconstruction. *Arthroscopy.* 2013;29:1322-1329.
9. Hewett TE, Ford KR, Myer GD. Anterior cruciate ligament injuries in female athletes part 2, A meta-analysis of neuromuscular interventions aimed at injury prevention. *Am J Sports Med.* 2006;34:490-498.
10. Kiesel K, Plisky P, Voight M. Can serious injury in professional football be predicted by a preseason Functional Movement Screen. *North Am J Sports Phys Ther.* 2007;2:147-158.
11. Cook G, Burton L, Hoogenboom BJ, et al. Functional movement screening: the use of fundamental movements as an assessment of function - part 1. *Int J Sports Phys Ther.* 2014;9:396-409.
12. Peate W, Bates G, Lunda K, et al. Core strength: A new model for injury prediction and prevention. *J Occup Med Toxicol.* 2007;2:3.
13. O'Connor FG, Deuster PA, Davis J, et al. Functional movement screening: predicting injuries in officer candidates. *Med Sci Sports Exerc.* 2011;43:2224-2230.
14. Cook G, Burton L, Kiesel K, et al. *Movement: Functional Movement Systems: Screening, Assessment, Corrective Strategies*. Aptos, CA: On Target Publications; 2010.
15. Cook G. *Athletic Body in Balance*. Champaign, IL: Human Kinetics; 2004.
16. Bell DR, Vesci BJ, DiStefano LJ, et al. Muscle activity and flexibility in individuals with medial knee displacement during the overhead squat. *Athl Train Sports Health Care.* 2012;4:9.
17. Stiffler MR, Pennuto AP, Smith MD, et al. Range of motion, postural alignment, and LESS score differences of those with and without excessive medial knee displacement. *Clin J Sports Med.* 2015;25:61-66.
18. Butler RJ, Plisky PJ, Southers C, et al. Biomechanical analysis of the different classifications of the Functional Movement Screen deep squat test. *Sports biomech.* 2010;9:270-279.
19. Kazman JB, Galecki JM, Lisman P, et al. Factor structure of the functional movement screen in marine officer candidates. *J Strength Cond Res.* 2014;28:672-678.
20. Gribble PA, Brigle J, Pietrosimone BG, et al. Intrarater reliability of the functional movement screen. *J Strength Cond Res.* 2013;27:978-981.
21. Onate JA, Dewey T, Kollock RO, et al. Real-time intersession and interrater reliability of the functional movement screen. *J Strength Cond Res.* 2012;26:408-415.
22. Lisman P, O'Connor FG, Deuster PA, et al. Functional movement screen and aerobic fitness predict injuries in military training. *Med Sci Sports Exerc.* 2013;45:636-643.
23. Swart E, Redler L, Fabricant PD, et al. Prevention and screening programs for anterior cruciate ligament injuries in young athletes. *J Bone Joint Surg Am.* 2014;96:705-711.
24. Myer GD, Ford KR, Brent JL, et al. Differential neuromuscular training effects on ACL injury risk factors in "high-risk" versus "low-risk" athletes. *BMC Musculoskelet Disord.* 2007;8:39.
25. Lehr M, Plisky P, Butler R, et al. Field-expedient screening and injury risk algorithm categories as predictors of noncontact lower extremity injury. *Scand J Med Sci Sports.* 2013;23:e225-e232.
26. Abraham A, Sannasi R, Nair R. Normative values for the functional movement screen in adolescent school aged children. *Int J Sport Phys Ther.* 2015;10:29-36.